EVALUATION OF THE DISBUDDING AND DEHORNING THECNIQUES IN CATTLE, THE CONSEQUENCES, AND PROPOSALS FOR IMPROVEMENT

Author: Clàudia Sánchez Rosell

Tutor: Ramon Armengol Gelonch

September 2018

Double bachelor's degree: Degree in Veterinary Medicine and Degree in Animal Science and Production

University of Lleida

ABSTRACT

Calve dehorning is a frequently applied procedure that is intended to facilitate the management and increase the safety of farmers and calves. This report aimed to review reasons for disbudding and dehorning, and the different common dehorning methods including the use of drugs during the procedure and use of pharmacological analgesic, anaesthetic and sedation drugs, and its benefits for stress- and pain alleviation. Also the determination of effect on the wellbeing and productive performance of calves. Calve welfare is significantly reduced during dehorning, as it causes stress and pain. Many studies point to minimization of the pain perceived by the use of pharmacological agents. Beneficial effects were observed with the combined use of a sedative and local anaesthetic allows disbudding and dehorning without immediate pain and stress response, and the addition of a nonsteroidal anti-inflammatory drug reduces the pain related responses during the hours following.

Key words: dehorning, disbudding, analgesic, anaesthetic, sedation, productive performance, stress, pain.

RESUM

El descornat en vedells és un procediment realitzat en freqüència que pretén facilitar el maneig i augmentar la seguretat dels grangers i vedells. Aquesta revisió bibliogràfica pretenia revisar els motius del desbotonat i descornat, i els diferents mètodes comuns de descornament, incloent-hi l'ús de fàrmacs durant el procediment i l'ús de fàrmacs analgèsics, anestèsics i de sedació, i els seus beneficis per a l'alleujament de l'estrès i el dolor. També la determinació de l'efecte sobre el benestar i el rendiment productiu dels vedells. El benestar dels vedells es redueix significativament durant el descornat, ja que causa estrès i dolor. Molts estudis apunten a la minimització del dolor percebut per l'ús d'agents farmacològics. Els efectes beneficiosos es van observar amb l'ús combinat d'un sedant i un anestèsic local, que permet el desbotonat i el descornat sense dolor immediat i la resposta a l'estrès, i l'addició d'un fàrmac antiinflamatori no esteroide redueix les respostes relacionades amb el dolor durant les hores posteriors.

Paraules clau: descornat, desbotonat, analgèsic, anestèsic, sedació, rendiment productiu, estrès, dolor.

RESUMEN

El descornado en los terneros es un procedimiento frecuentemente aplicado que tiene la intención de facilitar el manejo y aumentar la seguridad de los granjeros y terneros. Esta revisión bibliográfica tuvo como objetivo revisar las razones para el desmochado y el descornado, y los diferentes métodos de descornado comunes, incluido el uso de drogas durante el procedimiento y el uso de analgésicos farmacológicos, anestésicos y sedantes, y sus beneficios para aliviar el estrés y el dolor. También la determinación del efecto sobre el bienestar y el rendimiento productivo de los terneros. El bienestar de los terneros se reduce significativamente durante el descornado, ya que causa estrés y dolor. Muchos estudios apuntan a la minimización del dolor percibido por el uso de agentes farmacológicos. Los efectos beneficiosos se observaron con el combinado de un sedante y un anestésico local, que permitieron el desmochado i el descornado sin dolor inmediato y la respuesta de estrés, i la adición de un fármaco antiinflamatorio no esteroideo reduce las respuestas relacionadas con el dolor durante las horas posteriores.

Palabras clave: descornado, desmochado, analgésico, anestésico, sedación, rendimiento productivo, estrés, dolor.

INDEX

1. INTRODUCTION

The disbudding is done during the first 4-6 weeks of animal life, when the horn buttons are between 5 and 10 mm in length (AVMA, 2014). Disbudding methods destroy the horn-producing cells (corium) of the horn bud. Dehorning refers to the removal of the horn after attachment of the horn bud to the skull, occurring at approximately 2 months to 1 year of age ('CVMA | Documents | Disbudding and Dehorning of Cattle – Position Statement', n.d.). This practice is carried out for two main reasons: increasing the safety of the personnel in charge of handling these animals and reducing the injuries and their severity that calves may suffer, thereby increasing the well-being of the animal (Dogan & Demirci, 2012).

Several methods for disbudding cattle exist, but each method has its advantages and disadvantages. Hot-iron disbudding is commonly performed and it is reliable, but is considered to be quite painful (Mosher et al., 2013). Disbudding via cautery may create less distress than physical dehorning using a scoop because nociceptors are destroyed by heat and pain perception is consequently reduced. In the chemical disbudding, injection an alkaline paste on the horn bud, results in necrosis of the horn bud (Koger, 1976). However, pain-related behavioural changes are observed after the procedure and can last up to 3 or 4 hours (AVMA, 2014).

Dehorning causes behavioural changes during the procedure and for 6 to 8 hours afterwards. Amputation affects the skin, bone and sometimes the frontal sinus, causing deeper and more extensive lesions (AVMA, 2014).

This practice can be very painful and traumatic, as a result of this pain, calves may suffer behavioural changes associated with pain stress, decreasing their daily intake of concentrate and their immune status. Regardless of the dehorning and disbudding method, following the procedure a behaviour change is noted that is consistent with an acute stress response (Sylvester, 2004). This could lead to an increase in the risk in suffering pathologies such as neonatal diarrhoea or respiratory disease pain and behaviour signals (Stafford & Mellor, 2005). With the aim of reducing the pain caused by these procedures, it is recommended to use a combination of local anaesthesia and systemic sedative with non-steroidal anti-inflammatory drugs (NSAID) such as

meloxicam, flunixin, ketoprofen. (Allen et al., 2013; Glynn et al., 2013; Mcmeekan et al., 1998).

This study is a bibliographic research of the habitual techniques of disbudding and dehorning in calves, the recommendations that are carried out on the different techniques and the moment to execute them, the consequences about the behaviour of animals and their well-being.

2. OBJECTIVES

1) Description the usual techniques for disbudding and dehorning in calves.

2) Identification of different recommendations that are made about these techniques, including the use of drugs during the procedure and use of pharmacological analgesic, anaesthetic and sedation drugs, and its benefits for stress- and pain alleviation.

3) Determination of effect of disbudding and dehorning on the wellbeing and productive performance (ADG) of calves.

3. METHODOLOGY

3.1 Resources used

The databases used include: Google Scholar (-Google Academic, 2018), a Google search engine specializing in content and scientific-academic literature; Web of Science (-Web of Science, 2018), online scientific information service provided by Thomson Reuters; and PubMed (-Home - PubMed - NCBI, 2018), a free access database specialized in literature on health sciences.

3.2 Historical study about the relevance of disbudding and dehorning in calves

Initially, search was set about the impact of disbudding and dehorning annual research and has been analyzed through the Web of Science using the following keywords: ("disbud* calves") AND ("dehorn* calves"). In this way, a Citation report was generated from 2000 to 2018, with the aim of generating a graph with the number of publications and annual appointments (Figure 1) and the result was 253 studies.

Figure 1: Number of publications per year in the topic of disbudding and dehorning calves from 2000 to 2018.

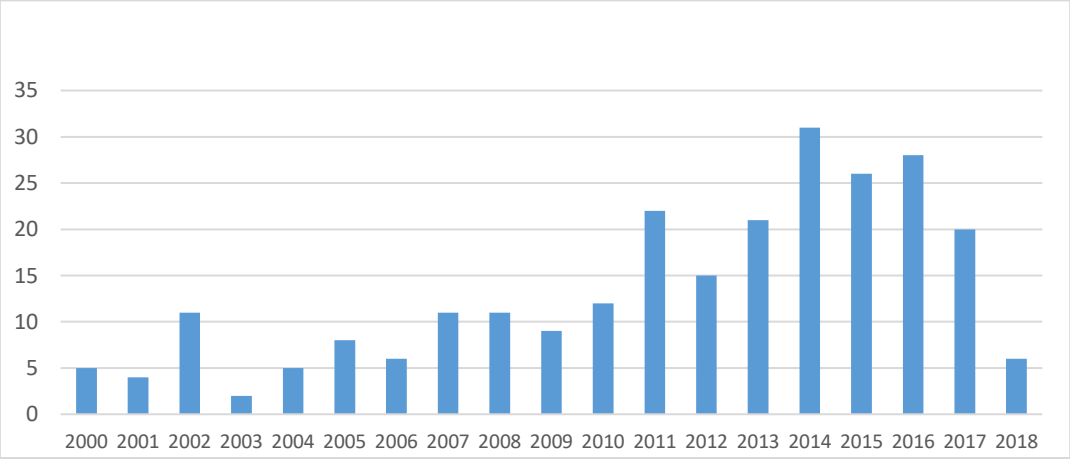

Figure 2: Number of annual appointments in publications related to disbudding and dehorning to calves from the year 2000 until 2018, and the result was 3.924 studies.

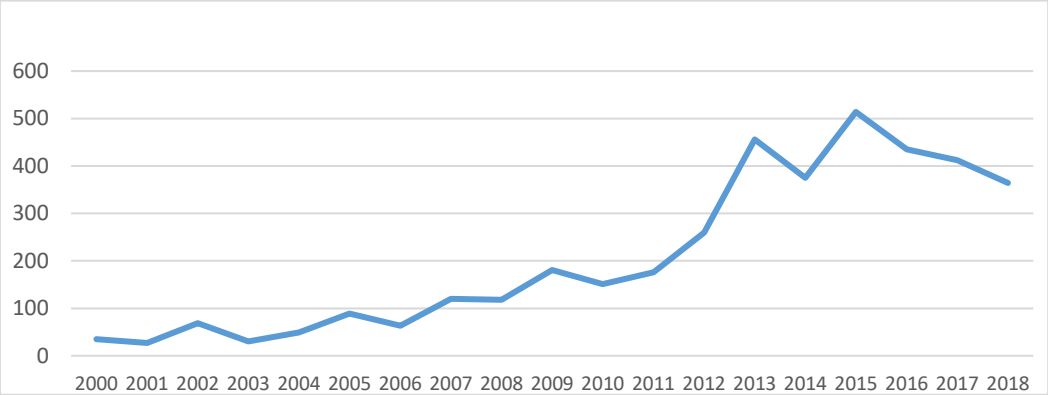

Figure 1 shows the number of studies related to disbudding and dehorning during the last 18 years, while Figure 2 presents the number of annual appointments of related articles. As shown, both the number of studies and the number of appointments has increased in recent years (2000 until 2008), which indicates an increase in research and concern for this practice.

3.3 Previous organization

One of the main challenges that involves a bibliographic review, on a minimally extensive subject matter, is the large amount of information that is obtained in the search. For this reason, good planning is especially important, both in the search for information and in the organization of it. To efficiently organize the information search process, it is necessary to carry out a division of the subject in various sets of information, which are attributed to certain keywords. In this way, when using keywords, we will obtain information relative to a particular set, excluding the one that belongs to another set. In this sense, the information was classified in three main themes:

• Techniques of disbudding and dehorning described in the literature.

• Practical recommendations at the same time to carry out these techniques (optimal age to perform, anaesthesia and analgesia used ...).

• Effects of the disbudding and dehorning on behaviour, the health status (welfare) and the productive performance (ADG) of calves.

4. REVIEW

4.1 Benefits of disbudding / dehorning

Disbudding and dehorning calves are a simple cost-effective practice that convey different advantages (Stafford & Mellor, 2005). If calves are disbudded early in life, there are few complications; however, some labor and equipment are required. Horns are the single major cause of carcass wastage due to bruising, and trim associated with bruising for carcasses from horned cattle is approximately twice that for carcasses from hornless cattle (Huertas, van Eerdenburg, Gil, & Piaggio, 2015).

Dehorned cattle require less feeding trough space; are easier handled and cause fewer injuries during transportation; present a lower risk of interference from dominant animals at feeding time; pose a reduced risk of injury to the rib, loin, round, eyes and other high-pieced cuts of other cattle; present a lower injury risk for handlers; exhibit fewer aggressive behaviours associated with individual dominance; and may incur fewer financial penalties on sale (Gottardo et al., 2011).

According to the conclusions of the ALCASDE project 2009, which evaluated practices and alternatives to disbudding in Europe, livestock prefer disbudding to dehorning, because the first is a faster method it's done in calves and the second is a surgery intended for older animals with developed horns and is performed by a veterinarian (Oliver, 2009).

4.2 Techniques of disbudding described in the literature

The disbudding is done during the first 4-6 weeks of animal life, when the horn buttons are between 5 and 10 mm in length (Farm Animal Welfare Education Centre, 2012). Horn buds are removed without opening the frontal sinus. Disbudding methods destroy the horn-producing cells (corium) of the horn bud. It can be performed by cauterization using a hot iron (hot-iron disbudding), chemical application of a caustic paste on the horn buds (chemical disbudding), or bud amputation using scoop dehorners (surgical disbudding) (Vickers, Niel, Kiehlbauch, & Weary, 2005; Winder et al., 2017).

4.2.1 Hot-iron disbudding

Methods of disbudding of the horn bud stage include thermal cauterisation. Hot-iron disbudding, also termed cautery disbudding or thermal disbudding (Hokkanen, 2015) means that calf horn bud tissue is destroyed by burning with a heated metal bar with a concave tip, which may be heated using an electric current or gas. Disbudding is carried out when horn buds are 5–10 mm long, easily palpable and a heated disbudding iron can be used alone usually on calves up to around 8 weeks of age (Stafford & Mellor, 2005). This method is quick and does not cause any abundant bleeding when performed properly. Cauterization is performed at a temperature of about 600ºC, for 15 to 60 seconds (Stilwell et al., 2012). This leads to the destruction of all the epidermal and dermal skin layers through to the subcutaneous tissue at the burn site. In addition, it causes tissue damage and oedema around the burn, and thus increases the sensitized area around the burned horn bud (Junger et al., 2002). The time for the procedure is prolonged when the dehorning device is not heated enough. High temperature causes the damage of skin tissues and horn buds. It concurrently causes cauterization of blood vessels and prevents bleeding (Stafford & Mellor, 2011).

4.2.2 Chemical disbudding

Chemical disbudding uses a very alkaline stick or paste (typically sodium or calcium hydroxide with a pH of 14) to cause a chemical burn, effectively destroying the germinal tissue of the horn bud (Stock et al., 2013). Injection of calcium chloride under the horn bud results in necrosis of the horn bud, but its administration without prior sedation and/or local anaesthesia is not recommended due to the level of discomfort induced by the procedure (Koger, 1976). Applied to the horn bud can damage surrounding skin and/or the eyes if runoff occurs; as long as the active chemical is in contact with tissue, damage continues (Caray, de Boyer des Roches, Frouja, Andanson, & Veissier, 2015).

Application of caustic paste is acceptable in calves after 1 day of age up to 7 days old, but anaesthesia is required if calves are disbudding after this period age (Gottardo et al., 2011). Although the use of caustic paste is recommended by manufacturers at less than 1 week of age in the United Kingdom, the mean age of caustic paste use in the United States is 2.3 weeks, and 24% dairy producers in Ontario using caustic paste apply this at more than 4 weeks of age (Winder et al., 2017).

4.2.3 Bud amputation using scoop dehorners (surgical disbudding)

Dehorning spoons or tubs provide a quick and efficient technique for removing horn and a small ring of skin encircling it. The surgical removal of the bud can be carried out up to an age of 2 to 3 month. There are different devices to conduct the procedure, e.g. tube (Fig. 3), scoop (Fig. 4). Studied in connection with scoop dehorning, local anaesthesia before disbudding are bupivacaine, which is effective for approximately 4 hours (McMeekan et al., 1998). The sharp end of the scoop or tube is placed over the bud and rotated to isolate the central core of the buds. The cutting edge is then used as a gouge to get the punched part completely loose by abrasing the underside (Rosenberger, 1970). Possibly occurring bleeding can be stopped by cauterisation or ligature, the remaining wound should be disinfected and should heal within 3 to 4 weeks (Gottschalk et al., 1992). The knife is drawn through the skin towards and through the horn, slicing off the horn. This will remove the horn plus about 1/8 inch of skin around the entire horn bud. To ensure that no horn-forming tissue is left, the ring of hair around the bud has to be removed completely.

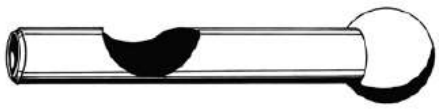

*Figure 3: A dehorning tube (*source from*: Anderson, 2009).*

*Figure 4: A Barnes-type dehorner scoops the horn and horn-producing skin surrounding the horn base (*source from*: Anderson, 2009).*

4.3 Techniques of dehorning described in the literature

Dehorning refers to the removal of the horn after attachment of the horn bud to the skull, occurring at approximately 2 months to 1 year of age (La Fontaine, 2006).The presence of the cornual diverticulum of the frontal sinus causes surgical dehorning of adult cattle to be more invasive (Ward & Rebhum, 1992). Dehorning of adult cattle is associated with increased risks of sinusitis, bleeding, prolonged wound healing and infection (McMeekan et al., 1998). The horn grows from the skin at the base of the horn, when done correctly, dehorning will both remove the horn and also prevent it from regrowing during the life of the animal.

A properly dehorned animal should have a 1/4 – 1/2 inch wide ring of skin at the base of the horn removed to prevent horn regrowth. A squeeze chute or head gate also and a head and nose bar will aid in restraining the animal's head will be needed for older calves. Be pre pared to stop bleeding after dehorning and to care for two large, open head wounds for a period of time (Stanton, 2016).

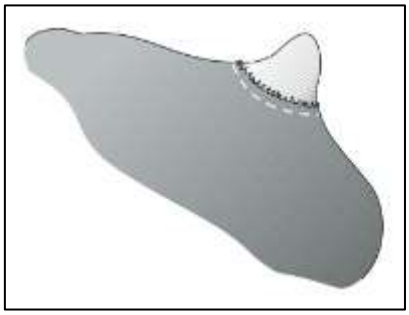

Figure 5: Proper location for horn removal (source from*: Stanton, 2016).*

Physical methods of dehorning (gouge dehorning) include the use of embryotomy wire, guillotine shears, or dehorning knives, saws, spoons, cups, tubes, or high tension rubber bands. The Barnes-type scoop dehorner is commonly used for physical dehorning. When cattle have large horns they are sometimes "tipped", a procedure that removes the sharp end of the horn but leaves the base. Once horn development has commenced horn cutting or sawing at the base of the horn close to the skull is needed. To remove the corium and prevent horn regrowth, a complete ring of hair surrounding the horn bud should also be removed.

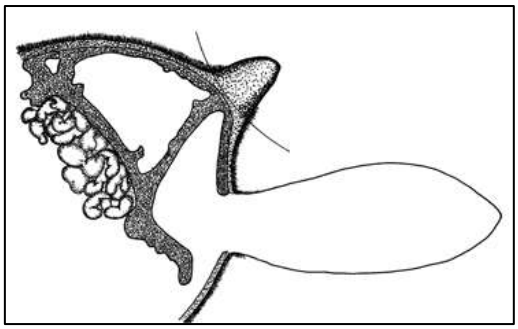

*Figure 6: The Barnes-type dehorner removes horn-producing skin calves with the horn attached to the skull, the dehorner cuts into the frontal sinus (*source from*: Anderson, 2009).*

Hand saws, obstetrical wire and keystone dehorners are generally reserved for use on older cattle with larger horns. Ideally, the need to dehorn animals greater than 1 year of age is infrequent.

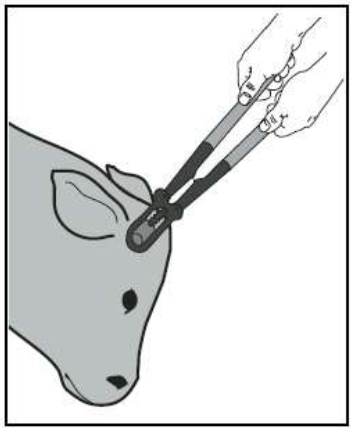

Figure 7: Using Keystone5 (source from: Stanton, 2016)*.*

Following dehorning, bleeding is more likely with older cattle. Artery clamps, can be used to reduce the bleeding, grab the artery and slowly pull it away from the head until it breaks. After bleeding has slowed or stopped, apply blood coagulation powder and fly spray to the wound (Oxytetracycline, Clorviogen Lamons), this reduces the like li hood of continued bleeding and infections. The calf should then be released into a quiet, shaded environment so its blood pressure will go down. Close observation of the calves for about 10 days and continued fly control is important. Doing the job early in life, having good restraint and using an appropriate cleaned and disinfected instrument should prevent any problems (Stanton, 2016).

4.4 Alternatives to disbudding and dehorning

Because all methods for destroying horns are painful for the animals (Stafford & Mellor, 2005), alternative options to disbudding and dehorning need to be considered. One practical alternative to disbudding, and to eliminating disbudding-related pain, might include using genetics to breed hornless cattle (Guatteo et al., 2012).

Some cattle breeds are polled, but most dairy breeds and many beef breeds, still produce horns. It is possible to breed polled European type cattle (Bos taurus) because there is a simple genetic basis for polledness (Prayaga, 2007; Spurlock, 2014). Recently, the location of the polled locus has been narrowed down to chromosome 1 (BTA1) in Bos taurus. A single perfectly associated insertion/deletion variant (P202ID) in Simmental and other beef cattle has been found.

However, there is large scope for new research to be conducted, developing an understanding of possible relationships and confounding effects between the polled and scur horn genes. Leading to the development of genetic tests able to identify homozygous/heterozygous animals for polled and scur horn genes (Prayaga, 2007).

It is widely believed that the removal of horns from Nova Zeeland cattle herds via genetics is not achievable, as there is a very small gene pool of polled dairy cattle, and thus there is a risk of losing genetic merit within herds. However, this may have been the case a decade ago, but bulls have since been bred that are polled and have moderate to high estimated breeding values and Breeding Worth (Armour, 1994).

This includes economic savings due to reduced labour (both on farm and at slaughter), the improved health and well-being of calves through reduced stress (therefore no setbacks) and hornless cattle remove any speculation involving animal welfare issues.

4.5 Optimal age to perform

Disbudding at or near birth may present a practical strategy for mitigating pain; less tissue may be damaged if a smaller iron tip is used and, as a result, the wound may heal faster (Newsome, Mason, & Pruitt, 1973). Several organizations recommend that the procedure be performed at the youngest practical age, which is in-creasingly interpreted as less than 1 week of age (American Association of Bovine Practitioners, 2014; National Milk Producers Federation, 2016; American Veterinary Medical Association, 2018). For example, the European Convention, which applies to 47 countries, recommends that pain relief be used when disbudding calves over 4 week of age (Council of Europe, 1988). In the United Kingdom, disbudding with a hot iron is preferred to dehorning and it is advised that this should be performed before cattle reach the age of 2 months (FAWC). Australian and New Zealand authorities recommend disbudding at the youngest age possible, and chemical dehorning is not deemed to be acceptable unless it is performed within the first few days after birth (National Animal Welfare Advisory Committee, 2005). However, only 20% of these receive any medication during the disbudding in Europe (ALCASDE, 2009).

Stilwell et al. (2010) revealed that only 12.4% of the US dairy cattle breeders use analgesic agents during this procedure. In Australia, dehorning without local anaesthesia or analgesia is restricted to animals less than 6 months old (Misch et al., 2007). The New Zealand Code of Welfare for Painful Husbandry Procedures mandates a 9 month age limit for dehorning without attention to pain relief (National Animal Welfare Advisory Committee, 2005). The 1992 Animal Rights Law in Sweden requires that dehorning via cautery be performed under anaesthesia/sedation. In Denmark, calves up to 4 weeks old can be dehorned without application of a local anaesthetic (Stafford & Mellor, 2005). In some European countries, this treatment procedure is not allowed without anaesthesia in calves older than 7 days (Doherty et al., 2007). General standards of calf protection in the area of the European Union are based on Council Directive 91/629/EEC and Council Directive 97/2/EC. However, numerous European countries have not included more detailed legal regulations in their local national law so far.

4.6 The effect at the disbudding/dehorning

4.6.1 Pain sensitivity

Pain may be experienced more intensely at younger ages due to the rapid activation of awareness soon after birth. In addition, painful experiences in neonates can alter development of neural pain pathways, leading to a systemic increase in pain sensitivity (humans: Taddio et al., 1997). Further research is needed to confirm whether persistent increases in pain sensitivity occur after disbudding close to birth.

Disbudding or dehorning occurs before 8 week of age, which indicates these calves would have been disbudded rather than dehorned, and would experience less pain than animals dehorned by amputation at older ages (Petrie et al., 1996). That said, it is difficult to compare perceptions of pain between studies, not only because the populations and methods differ, but the list of procedures and conditions given to participants differed in our work and may confound comparisons between studies. Producers who are more sensitive to pain take the pain of dehorning more seriously (Wikman et al., 2013).

Farm animals are indispensably accompanied by stress, irrespective of the method, the procedure of disbudding and dehorning is painful and stressful. The methodologies used to measure stress include direct observations of the specific behaviours ear flicks, head shakes, and head rubbing. Also an assessment of physiological reactions such as heart rate variability, blood pressure or the changes in stress hormones concentration (Ayala et al., 2012). They often behave in apathetic manner, lie with their heads at side and do not react to other individuals from the group (Stilwell et al., 2012).

On average, wounds took, 9 week to re-epithelialize and are painful throughout this time, raising concerns about the welfare implications of this practice. This result is consistent with healing times reported for hot-iron brands, which take at least 10 week to re-epithelialize in 4 to 7 old beef calve (Adcock & Tucker et al., 2014).

Horn bud up to the 6-8 weeks of life is freely embedded in skin layer above the skull. With age, the bud connects to periosteum of the frontal bone, and at this stage dehorning procedure is more painful (Parsons & Jensen, 2006), therefore hot-iron disbudding is painful (Stock et al., 2013). Disbudding near birth does not improve welfare

outcomes, also does not alter; rather, some evidence suggests it may produce a generalized long-term increase in pain sensitivity (Adcock & Tucker et al., 2014).

In addition to acute pain, injury can cause prolonged inflammation that can persist until the wound is healed, which can take months for burns such as hot-iron brands in cattle. A consistent feature of inflammation is an increased pain response to stimulation around the wound. It is unknown how long wounds remain sensitive following disbudding, as studies have largely focused on the first few hours or days following the procedure (Adcock & Tucker, 2018).

Regardless of treatment, the highest concentration of cortisol is observed up to 1.5 hours after dehorning, this response suggests that amputation dehorning causes marked pain induced distress for at least 7–9 h (Figure 8). The changes in blood cortisol concentration suggest that dehorning using surgical method causes a considerable pain (Stafford and Mellor, 2005).

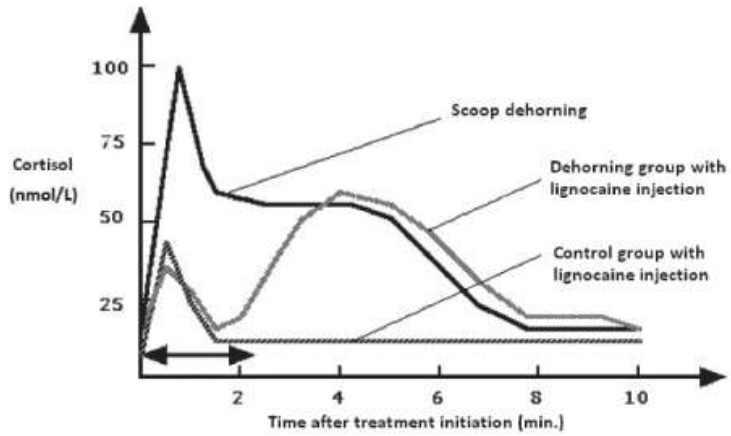

Figure 8: Plasma cortisol concentration of calves aged 20-24 weeks after scoop dehorning with lignocaine injection (Sylvester et al., 1998).

4.6.2. Health sensitivity

Dehorning and disbudding procedures is also relateds to a distinct effect on the immune system, leads to leukocytosis and neutrophilia (Doherty et al., 2007). Dehorning with hot iron provokes not only suppressive effect on leucocyte response, but is also connected to acute phase response via an increase in blood haptoglobin level (Ballou et al., 2013). The mechanism of suppressive activity on leucocytes is probably of multi-factorial character and does not result entirely from an increase in cortisol level (Earley et al., 2010). It should be stated in the summary that calf dehorning causes a distinct neurohormonal response via an effect on the hypothalamic-pituitary-adrenal axis and

autonomic nervous system (Chiu et al., 2012). It is a painful procedure causing changes in behaviour, physiological parameters and an increase in stress hormones secretion (Grøndahl- Nielsen et al., 1999; Stewart et al., 2008; Heinrich et al., 2009; Ballou et al., 2013).

4.6.3 ADG

Sporadically, wound healing after dehorning may last for a long time leading to a decrease in production indices. Additionally, ketoprofen treated calves tended to gain more weight during the total observation time of 24 hours after disbudding compared to control animals (Faulkner & Weary, 2000).

Dairy calves given free access to milk consume more than 8L (Khan, Weary, & von Keyserlingk, 2011). Calves disbudded at 35 days of age may be better equipped to meet these nutritional requirements due to increased milk rations and solid feed intake, and a more developed digestive tract and thermoregulatory response (Hulbert & Moisa, 2016).

Accordingly, ADG was twice as high between 35 and 42 d than between 3 and 10 d of age in Adcock & Tucker (2018) study. A similar age pattern in ADG in conventionally fed dairy calves has been reported by Jasper & Weary (2002).

In those calves not disbudded, ADG increases comparing to the rest of the groups. Accordingly, this practice is affecting their growth potential (Own data, not published).

4.7 Options for alleviating disbudding / dehorning – related pain

The highest concentration of cortisol (stress indicator) is observed up to 1.5 hours after dehorning procedure (Kupczyński, Budny, Śpitalniak, & Tracz, 2014). Regardless of whether anaesthesia will be used or not directly after dehorning, as well as irrespective of the age of calves, the cortisol eruption was observed and the values were above baseline concentrations for 30 min following dehorning (Allen et al., 2013; Mosher et al., 2013). The cortisol response suggests that amputation dehorning causes marked pain induced distress for at least 7–9 h and this conclusion is supported by the behaviour of calves (Stafford & Mellor, 2005).

The animals which were subjected to local anaesthesia and were administered an NSAID showed more proper behaviour patterns, and cortisol concentration in blood decreased,

similar to heart rate and respiration rate, and assures good welfare for 24 h after dehorning (Stilwell et al., 2012). The effectiveness of local anaesthesia and NSAIDs application during dehorning was confirmed in another study (Ballou et al., 2013). In regard, the most behavioural responses are largely reduced when pain relief in the form of local anaesthetics or non-steroidal anti-inflammatory drugs (NSAIDs) are administered (Stafford and Mellor, 2005), therefore, disbudding is likely to induce intense pain in calves.

Local anaesthesia with lidocaine application lasts up to 2 hours, and this time may be increased for the next 2 hours using bupivacaine (Stafford and Mellor, 2005). Local anaesthesia (bupivacaine) together with anti-inflammatory drugs (ketoprofen) practically eliminate cortisol eruption after dehorning (*Figure 9*).

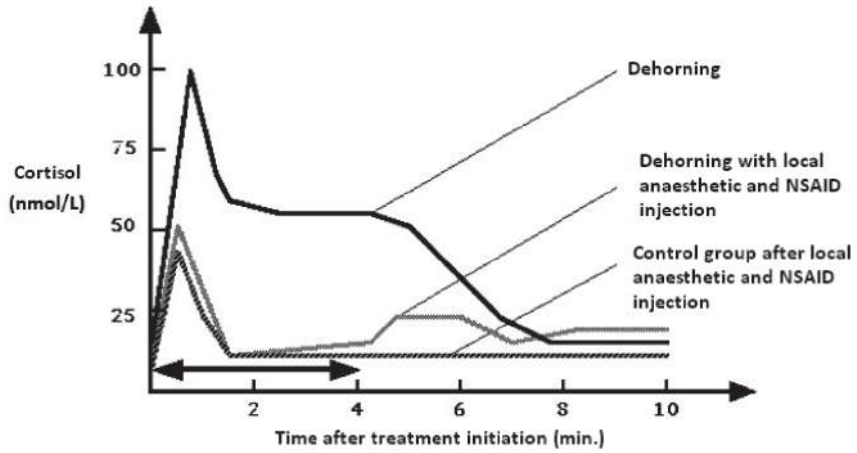

Figure 9: Plasma cortisol concentration of calves aged 12-16 week after scoop dehorning with local anaesthetic (bupivacaine) and NSAID (ketoprofen) injection (McMeekan et al., 1998).

4.7.1 Sedatives, α2 -adrenoceptor agonists

Sedatives are used prior to disbudding and dehorning procedure, usually to make handling of calves easier and less stressful for the calves, and also for the safety of the operator. However, sedation made the administration of local anaesthetic easier and thus eliminated the need for physical restraint during the administration, of the local anaesthetic and during procedure.

Grøndahl-Nielsen et al. (1999) showed that sedation with xylazine combined with butorphanol (anaesthesia), used in different groups of calves before hot iron disbudding, and reduced the physical activity in calves during procedure. But that sedation without

anaesthesia was not effective in reducing the cortisol response to disbudding, and only slightly reduced vigorous head jerks during disbudding compared to non-sedated animals. Also it was reported that calves treated with only xylazine showed a strong behavioural response to hot-iron disbudding (Faulkner & Weary, 2000; Stilwell et al., 2010). Therefore, they should not be used without local anaesthetic during hot-iron disbudding.

4.7.2 Local anaesthetics

The cornual nerve, a branch of the Trigeminal nerve (cranial nerve V), provides sensation to the skin of the horn/bud region. Injection of a local anaesthetic around the cornual nerve, as it traverses the frontal crest, desensitizes this region (Frandson et al., 2003). Partly different results regarding local anaesthesia effects on physiological and behavioural pain indications towards disbudding/dehorning have been obtained in different experimental investigations (Morisse et al., 1995; Petrie et al., 1996; McMeekan et al. 1998a, b; Sylvester et al., 1998; Grøndahl-Nielsen et al., 1999; Graf & Senn, 1999; Sutherland et al., 2002; Sylvester et al., 2004; Vickers et al., 2005; Stilwell et al., 2009). They may partly be due to different disbudding methods applied in calves of different ages (caustics: 10 to 35 days, hot iron: 10 days to 8 weeks, scoop disbudding: 6 weeks, scoop dehorning: 3 to 6 months) and different implementations of local anaesthesia, e.g. as regards applied volumes of the anaesthetic.

In the case of chemical dehorning, Braz et al. (2012) it was proved in that study that an application of caustic paste causes strong pain for the first 30 minutes after application. Pharmacological control of cutting (sedation) is recommended in the case of this dehorning method. According to Vickers et al. (2005), local anaesthesia is not effective, while Stilwell et al. (2009) demonstrated that the pain may be controlled using local anaesthesia together with an application of flunixin meglumine. For instance, Morisse et al. (1995) observed an incomplete to lacking effectiveness of anaesthesia during caustic. Also Vickers et al. (2005) did not find a significant reduction of behavioural indicators of distress despite application of a local anaesthetic prior to disbudding with caustic paste. They presumed that the basic pH of the caustic paste negatively affected the action of the local anaesthetic. However, volumes of the anaesthetic used (1.5 ml lidocaine to block the cornual nerve and 3 ml s.c. at the base of the horn) might have

been insufficient, as Stilwell et al. (2009) concluded from their study that even 5 ml of 2 % lidocaine injected around the cornual nerve was efficient in reducing, but not preventing cortisol rise and pain-related behaviours.

However, considered other factors such as poor handling of calves or individual differences in the neural topography of the horn area as potential causes. Efficacy of the anaesthesia should always be controlled before disbudding by testing sensitivity of the skin around the horn bud by pricking (DEFRA, 2003; Stilwell et al., 2009). Because Weary (2000) warns that differences in the behavioural response between treated and untreated calves can be sufficiently subtle so that it is difficult for observers to be certain if adequate nerve blockage was achieved. This also means that the person doing the disbudding should always allow enough time for the anaesthetic to numb the area before they begin (DEFRA, 2003). Recent studies indicate that calves treated with local anaesthetics actually have higher plasma cortisol levels than untreated animals after the local anaesthetic looses its effectiveness (McMeekan et al., 1998a; b; Graf & Senn, 1999).

In regard for hot iron disbudding, Stafford & Mellor (2005) concluded in their review that in principle a corneal nerve blockade using lignocaine reduces immediate behavioural pain responses like escape behaviour seen during the disbudding/dehorning procedure and eliminates the plasma cortisol response for the duration of its action. However, calves disbudded using a local anaesthetic still require restraint, because calves respond to both, the pain of the procedure and to the physical restraint.

Lidocaine (2%) (Duffield et al., 2010; Graf and Senn, 1999; Grøndahl-Nielsen et al., 1999; McMeekan et al., 1999) is the most popular local anaesthetic used in hot-iron disbudding-related studies as a corneal nerve block (Stilwell et al., 2012) usually given at 5 mL/horn 10 min before disbudding (Duffield et al., 2010; Heinrich et al., 2009). Lidocaine blocking effect persists for 60–90 min after injection (Anderson & Muir, 2005) based on both behavioural and physiologic changes. Also, Morisse et al. (1995) observed hot iron disbudding while 60 % remained motionless showing no evidence of pain.

A study investigated the use of cautery following amputation dehorning and using lidocaine local anaesthesia before amputation dehorning in 20 to 24 week old calves.

The integrated cortisol response over a 9-hour period indicated a significantly diminished the cortisol response by 75%. Local anaesthetics provided to cattle before dehorning have been shown to aid in the mitigation of the initial acute cortisol response.

On the other hand, Doherty et al. (2007) applied various concentrations of lidocaine and proved, based on behaviour observations, that an application of 5% lidocaine solution does not assure higher comfort after dehorning, but reduces stress reactions during the procedure and thus dehorning becomes more safe. Consistent cortisol changes are significantly reduced or eliminated during the acute phase of the pain response. The study demonstrated that anaesthetic agents, once the desensitization associated with local infusion of lidocaine has diminished, cortisol concentrations significantly increase in blood in comparison with animals dehorned without lidocaine. Although a few studies have indicated no difference in the pain or stress response following the provision of a local anaesthetic before dehorning, most studies support its use because of a near elimination of the acute behaviour and physiologic changes that are typically observed (Graf & Senn, 1999; Grøndahl-Nielsen et al., 1999).

The injection of the anaesthetic provokes transient stress and pain, not primarily due to the puncture itself, but presumably due to the pressure caused by the injected volumes (Graf & Senn, 1999). However the slight rise of cortisol concentration and defence actions often ceased already during the injection, because anaesthetisia rapidly takes effect (Graf & Senn, 1999).

4.7.3 Non-steroidal anti-inflammatory drugs, NSAIDs

Previous research thus suggests that NSAIDs, are effective in alleviating pain during hot-iron disbudding and for several hours after it. The results of oral meloxicam administration are similar to parenteral administration in following pain attenuation (Heinrich et al., 2009; Allen et al., 2013). Oral meloxicam can provide effective analgesic concentrations for several days after surgery based on average elimination half-lives of approximately 38.6 hours (Allen et al., 2013). In the recent study, Allen et al. (2013) observed that irrespective of the time of oral meloxicam administration (1 mg/kg) in powdered milk replacer 12 h before cautery dehorning or oral bolus (1 mg/kg) at the time of dehorning suppresses a pain response. This research suggests that meloxicam only prostaglandin E2 (PgE2) production was significantly affected by the timing of

meloxicam administration. Oral administration of ketoprofen (McMeekan et al., 1998a; Faulkner & Weary, 2000; Stilwell et al., 2012, Stafford & Mellor, 2005) in the milk 2 hours before and 2 and 7 hours after hot iron disbudding of 4 to 8 week old calves (combined with xylazine and lidocaine injections), significantly reduced head shaking 3 to 12 hours after disbudding and ear flicking 3 to 24 hours after disbudding compared to control animals only treated with xylazine and lidocaine. Furthermore, the treatment only with ketoprofen did not reduce the frequency of head rubbing at all, whereas the frequency of pain related behaviours in sham disbudded control calves were near zero (Faulkner & Weary, 2000).

McMeekan et al., (1998b) found that plasma cortisol and behavioural responses were kept close to baseline levels in the hours that follow dehorning, although there was a small but significant increase of cortisol concentration 30 minutes after dehorning. It is important to note that ketoprofen will have little effect on the pain caused by the amputation itself, as its action is on the inflammatory pain that starts not until 2 hours after disbudding/dehorning.

On this line, ketoprofen alone (injected intrajugularly 15 to 20 minutes before scoop disbudding) did not significantly reduce the initial peak in plasma cortisol concentration during the first 1 to 3 hours after disbudding compared to animals disbudded without ketoprofen, whereas the plasma cortisol concentration returned earlier to pre-treatment levels at about 2 hours rather than 8 hours after disbudding (McMeekan et al., 1998b). However, in calves younger than 2 weeks and disbudded by hot iron, intramuscular administration of ketoprofen in addition to lidocaine produced a reduction in cortisol concentration already within the first 3 hours after disbudding, but did not affect later cortisol responses up to 8 hours post to animals solely treated with lidocaine (Milligan et al., 2004).

The authors assume that the potentially beneficial effect of using NSAID increases with the size of the horn buds removed, as the amount of tissue damage and postoperative inflammatory pain should increase accordingly.

However, behaviour analysis shows a high incidence of pain-related behaviours at 3 h, suggesting that, although not causing a noticeable rise in plasma cortisol, discomfort is

present for longer time period (Stilwell et al., 2012). The study conducted by Stilwell et al. (2012) demonstrated that pain may persist up to 6 h after disbudding, and after regional anaesthesia and carprofen administration none of these calves showed any sign of pain at 24 h. According to Heinrich et al. (2009) the calves may experience the pain even up to 27 h after dehorning, but the authors highlight that there are differences in the time course and sensitivity of response variables. An application of NSAID did not affect significantly the play behaviour of calves (up to 27 h) and there was no difference between the treatments in head-related locomotor behaviours at either 3 or 27 h post disbudding (Mintline et al., 2013). Irrespective of pharmacological agents applications, the wounds around horn bud may remain sensitive for at least 75 h after the treatment (Mintline et al., 2013), must be considered the possibility of extending the analgesic treatment (Kleinhenz et al., 2018).

5. CONCLUSIONS

Table 1: Alleviating related pain disbudding / dehorning.

	ADVANTAGES	DISADVANTAGES
Local anaesthetics and NSAID	Cortisol concentration in blood decrease, behavioural responses are largely reduced and assures good welfare for 24h after dehorning. Caustic paste disbudding with treatment of local anaesthesia and NSAID provided effective reduction in pain as assessed.	
Sedatives	Are used prior to procedure, and thus eliminated the need for physical restraint during the local anaesthetic administration and during procedure, to make handling easier and less stressful for the calves, and also for the safety of the operator. The more weeks the calves have, the more useful it is.	Cannot be used alone, therefore, they should not be used without local anaesthetic.

Table 2: Alleviating related pain in disbudding with caustic paste and hot-iron.

	ADVANTAGES	DISADVANTAGES
Local anaesthetics	5 mL/horn of 2% lidocaine injected around the corneal nerve 10 min before disbudding, reduces stress reactions during the procedure and thus dehorning becomes more safe. Caustic paste disbudding causes distress for at least 3h and that local anaesthesia is efficient in controlling pain for the first hour but discomfort returns after the nerve blocking subsides.	Does not provide an adequate post-operative pain relief.
Sedatives	It has to be done with the calf sedated.	-
NSAID	-In calves younger than 2 weeks, intramuscular administration of NSAID with local anaesthetic produced a reduction in cortisol concentration and decrease in physiological reaction to stress already within the first 3 hours after procedure.	-Only NSAID not reduce the frequency of head rubbing and pain related behaviours. -The potentially beneficial effect increases with the size of the horn buds removed, as the amount of tissue damage and postoperative inflammatory pain should increase accordingly. -Extending the treatment because within the first 48 hours pain can be present.

1) Chemical disbudding with alkaline paste is better de 10 days and not need local anaesthesia. Hot iron cautery is better 10 and 21 days of age with local anaesthesia and NSAID. The surgical method is recommended when the horns reach the length >10 mm.
2) Whatever method of disbudding and dehorning is used, the procedure causes distress and pain in the treated animals.
3) It is a painful procedure causing changes in behaviour and physiological parameters (cortisol eruption), an increase in stress hormones secretion and affect their growth potential.
4) The combination of a sedative and local anaesthetic allows disbudding and dehorning without immediate pain and stress response, and the addition of a nonsteroidal anti-inflammatory drug reduces the pain related responses during the hours following disbudding and dehorning.
5) Local anaesthetics provided to cattle before dehorning have been shown to aid in the mitigation of the initial acute cortisol response, but does not provide an adequate post-operative pain relief. Efficacy of local anaesthesia should be individually controlled.

6. REFERENCES

Adcock, S. J., & Tucker, C. B. (2018). The effect of disbudding age on healing and pain sensitivity in dairy calves. *Journal of Dairy Science*, 1–13.

Allen, K. A., Coetzee, J. F., Edwards-Callaway, L. N., Glynn, H., Dockweiler, J., KuKanich, B., & Bergamasco, L. (2013). The effect of timing of oral meloxicam administration on physiological responses in calves after cautery dehorning with local anesthesia. *Journal of Dairy Science*, *96*(8), 5194–5205.

American Association of Bovine Practitioners. (2014). Castration and dehorning guidelines. Retrieved 6 April 2018 from, http://www.aabp.org/resources/aabpguidelines/castrationanddehorning_guideles

Anderson D. E., Muir W. W. (2005). Pain management in cattle. *Veterinary Clinical Food Animal,* 21:623–635.

Armour, K., (1994). The Montreal Process and sustainable management of. *Lincoln University Digital Dissertation.*

AVMA. (2014). Literature Review on the Welfare Implications of the Dehorning and Disbudding of Cattle. *American Veterinary Medical Association*, 1–9.

Ayala, I., Martos, N. F., Silvan, G., Gutierrez-Panizo, C., Clavel, J. G., & Illera, J. C. (2012). Cortisol, adrenocorticotropic hormone, serotonin, adrenaline and noradrenaline serum concentrations in relation to disease and stress in the horse. *Research in Veterinary Science*, *93*(1), 103–107.

Ballou M.A., Suther land M.A., Brooks T.A., Hulbert L.E., Davis B.L., Cobb C.J. (2013). Administration of anesthetic and analgesic prevent the suppression of many leukocyte responses following surgical castration and physical dehorning. *Veterinary Immunology,* 151:285–293.

Beggs, S., G. Currie, M. W. Salter, M. Fitzgerald & Walker, S. M (2012). Priming of adult pain responses by neonatal pain experience: Maintenance by central neuroimmune activity. *Brain,* 135:404–417.

Braz M., Carreira M., Carolino N., Rodrigues T., Stilwell G. (2012). Effect of rectal or intravenous tramadol on the incidence of pain-related behaviour after disbudding calves with caustic paste. *Animal Behaviour Science,* 136: 20–25.

Caray, D., de Boyer des Roches, A., Frouja, S., Andanson, S., & Veissier, I. (2015). Hot-iron disbudding: Stress responses and behavior of 1- and 4-week-old calves receiving anti-inflammatory analgesia without or with sedation using xylazine. *Livestock Science*, *179*, 22–28.

Chiu I.M., von Hehn C.A., Woolf C.J. (2012). Neurogenic inflammation and the peripheral nervous system in host defense and immunopathology. *Nature Neuroscience,* 15:1063–1067.

CVMA. (2018). Disbudding and Dehorning of Cattle. *Position Statement.* Retrieved 6 September 2018, from https://www.canadianveterinarians.net/documents/disbudding-and-dehorning-of-cattle

Dogan, K. H. & Demirci, S. (2012). Livestock-handling related injuries and deaths. *Livestock Production,* 81-116.

Doherty, T. J., Kattesh, H. G., Adcock, R. J., Welborn, M. G., Saxton, A. M., Morrow, J. L., & Dailey, J. W. (2007). Effects of a Concentrated Lidocaine Solution on the Acute Phase Stress Response to Dehorning in Dairy Calves. *Journal of Dairy Science*, *90*(9), 4232–4239.

DEFRA. 2003. Code of recommendations for the welfare of Livestock, Cattle. *Defra Publications, London, United Kingdom.*

Duffield T. F., Heinrich A., Millman S.T., De Haan A., James S., Lissemore K. (2010). Reduction in pain response by combined use of local lidocaine anesthesia and systemic ketoprofen in dairy calves dehorned by heat cauterization. *Canadian Veterinary Journal*, 51: 283–288.

Earley B., Buckham S., Gupta S., Pang W. & Ting S. (2010). Biologic response of animals to husbandry stress with implications for biomedical models. *Animal Physiology*, 2: 25–42.

Farm Animal Welfare Education Centre. (2012). Impact of dehorning and disbudding on the well-being of calves. *The Farm Animal Fact Sheet. No.2.*, .

Faulkner P. M., Weary D. M. (2000). Reducing pain after dehorning in dairy calves. *Journal Dairy Science*, 83: 2037–2041.

Frandson, R.D., Wilke, W.L,. Fails, A.D. 2003. Anatomy and physiology of farm animals. Lippincott Williams & Wilkins, Philadelphia, 2003, 6th edition, p. 210.

Glynn, H. D., Coetzee, J. F., Edwards-Callaway, L. N., Dockweiler, J. C., Allen, K. A., Lubbers, B. & Kukanich, B. (2013). The pharmacokinetics and effects of meloxicam, gabapentin, and flunixin in postweaning dairy calves following dehorning with local anesthesia. *Journal of Veterinary Pharmacology and Therapeutics*, *36*(6), 550–561.

Gottardo, F., Nalon, E., Contiero, B., Normando, S., Dalvit, P. & Cozzi, G. (2011). The dehorning of dairy calves: Practices and opinions of 639 farmers. *Journal of Dairy Science*, *94*(11), 5724–5734.

Gottschalk, A., Alps, H., Rosenberger, E. (1992). Praktische Rinderzucht und Rinderhaltung (applied cattle breeding and cattle husbandry), *BLV Verlagsgesellschaft mbH*, München, Germany.

Graf, B. & Senn, M. (1999). Behavioural and physiological responses of calves to dehorning by heat cauterization with or without local anaesthesia. Appl. Anim. Behav. Sci. 62:153–171.

Grøndahl - Nielsen C., Simonsen H. B., Damkjer L. J., Hesselholt M. (1999). Behavioural, endocrine and cardiac responses in young calves undergoing dehorning without and with use of sedation and analgesia. *Veterinary Journal,* 158: 14–20.

Guatteo, R., Levionnois, O., Fournier, D., Guemene, K., Latouche, C., Mormede, P., Prunier, A., Serviere, J., Terlouw, C. & Le Neindre, P. (2012). Minimising pain in farm animals: The 3S approach—'Suppress, substitute, soothe'. Animal 6:1261–1274.

Heinrich A., Duffield T. F., Lissemore K. D., Squires E. J., Millman S. T. (2009). The impact of meloxicam on postsurgical stress associated with cautery dehorning. *Journal of Dairy Science*, 92:540–547.

Hokkanen, A., (2015). *Hot-iron disbudding pain in calves*. *Dissertationes Scholae Doctoralis Ad Sanitatem Investigandam Universitatis Helsinkiensis.*

Huber J., Arnholdt T., Möstl E., Gelfert C.C., Drillich M. (2013). Pain management with flunixin meglumine at dehorning of calves. *Journal of Dairy Science*, 96: 132–140.

Huertas, S. M., van Eerdenburg, F., Gil, A., & Piaggio, J. (2015). Prevalence of carcass bruises as an indicator of welfare in beef cattle and the relation to the economic impact. *Veterinary Medicine and Science*, *1*(1), 9–15.

Junger, H., Moore, A., & Sorkin, L., (2002). Effects of full-thickness burns on nociceptor sensitization in anesthetized rats. *Burns* 28:772-777.

Kleinhenz, M. D., Van Engen, N. K., Smith, J. S., Gorden, P. J., Ji, J., Wang, C. & Coetzee, J. F. (2018). The impact of transdermal flunixin meglumine on biomarkers of pain in calves when administered at the time of surgical castration without local anesthesia. *Livestock Science*, (*212*), 1–6.

Koger, L. M., Dehorning by injection of calcium chloride. *Veterinary Medical Small Animal Clinic* 1976;71(6):824-825.

Kupczyński, R., Budny, A., Śpitalniak, K. & Tracz, E. (2014). Dehorning of calves Methods of pain and stress alleviation - A review. *Annals of Animal Science*, *14*(2), 231–243.

La Fontaine D. Dehorning and castration of calves under six months of age. Retrieved 24 May 2018, from http://transact.nt.gov.au.

McMeekan, C. M., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N., & Gregory, N. G. (1998a). Effects of local anaesthesia of 4 to 8 hours' duration on the acute cortisol response to scoop dehorning in calves. *Australian Veterinary Journal*, *76*(4), 281–285.

Mcmeekan, C. M., Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N. & Gregory, N. G. (1998b). Effects of regional analgesia and/or a non-steroidal anti-inflammatory analgesic on the acute cortisol response to dehorning in calves. *Research in Veterinary Science*, *64*(2), 147–150.

McCracken, L., Waran, N., Mitchinson, S. & Johnson, C., B. (2010). Effect of age at castration on behavioural response to subsequent tail docking in lambs. *Veterinary Anaesthesia*, 37:375–381.

Milligan, B.N., Duffield, T., Lissemore, K. 2004. The utility of ketoprofen for alleviating pain following dehorning in young dairy calves. *Canadian Veterinary Journal* 45, 140-143.

Mintline E. M., Stewart M., Rogers A. R., Cox N. R., Verkerk G. A., Stookey J. M., Webster J. R., Tucker C. B. (2013). Play behaviour as an indicator of animal welfare: Disbudding in dairy calves. *Animal Behaviour Science*, 144: 22–30.

Mirra, A., Spadavecchia, C., Bruckmaier, R., Gutzwiller A. & Casoni, D. (2018). Acute pain and peripheral sensitization following cautery disbudding in 1- and 4-week-old calves. *Physiology Behaviour*, 184:248–260.

Misch L. J., Duffield T. F., Millman S. T., Lissemore K. D. (2007). An investigation into the practices of dairy producers and veterinarians in dehorning dairy calves in Ontario. *Veterinary Journal,* 48: 1249–1254.

Morisse, J.P., Cotte, J.P., Huonnic, D. 1995. Effect of dehorning on behaviour and plasma cortisol responses in young calves. *Animal Behaviour Science* 43, 239-247.

Mosher R., Wang C., Allen P. (2013). Comparative effects of castration and dehorning in series or concurrent castration and dehorning procedures on stress responses and production in Holstein calves. Journal Animal Science, 91: 4133–4145.

National Animal Welfare Advisory Committee. (2005). *Animal Welfare (Painful Husbandry Procedures), No.7*.

National Milk Producers Federation. (2016). FARM Animal Care Reference 6 April 2018, from http://www.nationaldairyfarm.com

Newsome, T. W., Mason, A. D., & Pruitt, B. A. (1973). Weight loss following thermal injury. *Annals of Surgery*, *178*(2), 215–217.

Oliver, A. (2009). Study on the improved methods for animal-friendly production, in particular on alternatives to the castration of pigs and on alternatives to the dehorningof cattle. *ALCASDE.*

Parsons C., Jensen S. (2006). Dehorning Cattle, Western Beef Resource Committee, Cattle Producer's Library, Management Section CL750, University of Idaho and Oregon State University (2006).

Petrie, N. J., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N. (1996). Cortisol response of calves to two methods of disbudding used with or without local anaesthetic. *New Zealand Veterinary Journal* 44, 9-14.

Prayaga, K. C. (2007). Genetic options to replace dehorning in beef cattle—a review. Aust. J. Agr. Res. 58: 1–8.

Rosenberger, G. 1970. Krankheiten des Rindes (diseases of cattle). Verlag Paul Parey, Berlin und Hamburg, Germany, p. 45, 46,49, 619.

Spurlock, D. M., Stock, M. L. & Coetzee, J. F. (2014). The impact of 3 strategies for incorporating polled genetics into a dairy cattle breeding program on the overall herd genetic merit. *Journal Dairy Science*. 97:5265-5274

Stafford, K. J. & Mellor, D. J. (2005). Dehorning and disbudding distress and its alleviation in calves. *Veterinary Journal*, *169*(3), 337–349.

Stafford, K. J. & Mellor D. J. (2011) Addressing the pain associated with disbudding and dehorning in cattle Applied Animal Behaviour Science. *Veterinary Journal.* 135: 226-231.

Stanton, A. (2016). Dehorning Calves. *Agricultural Extension Service.* 235-245.

Stewart M., Stafford K.J., Dowling S.K., Schaefer A.L., Webster J.R. (2008). Eye temperature and heart rate variability of calves disbudded with or without local anaesthetic. Physiology Behaviour, 93: 789–797.

Stilwell G., Lima M.S., Carvalho R.C. & Broom D.M. (2012). Effects of hot-iron disbudding, using regional anaesthesia with and without carprofen, on cortisol and behaviour of calves. *Journal of Veterinary Science*, 92: 338–341.

Stilwell, G., Campos de Carvalho, R., Lima, M.S., Broom, D.M. 2009. Effects of caustic paste disbudding, using local anaesthesia with and without analgesia, on behaviour and cortisol of calves. *Animal Behaviour Science* 116, 35–44.

Stock, M. L., Baldridge, S. L., Griffin, D. & Coetzee, J. F. (2013). Bovine Dehorning. Assessing Pain and Providing Analgesic Management. *Veterinary Clinics of North America - Food Animal Practice* (Vol. 29).

Sutherland, M.A., Mellor, D.J., Stafford, K.J., Gregory, N.G., Bruce, R.A., Ward, R.N. 2002. Effect of local anaesthetic combined with wound cauterisation on the cortisol response to dehorning in calves. *Australian Veterinary Journal* 80, 165-167.

Sylvester, S. P., Stafford, K. J., Mellor, D. J., Bruce, R. A. & Ward, R. N. (1998). Acute cortisol responses of calves to four methods of dehorning by amputation. *Australian Veterinary Journal*, *76*(2), 123–126.

Sylvester, S. P., Stafford, K. J., Mellor, D. J., Bruce, R. A. & Ward, R. N. (2004). Behavioural responses of calves to amputation dehorning with and without local anaesthesia. *Australian Veterinary Journal*, *82*(11), 697–700.

Taddio, A., Katz, A., Ilersich, L. & Koren, G. (1997). Effect of neonatal circumcision on pain response during subsequent routine vaccination. *Lancet* 349:599–603.

Tucker, C. B., Mintline, E. M., Banuelos, J, K., Walker, A. B., Hoar, A., Varga, A., Drake, D. & Weary, D. M. (2014b). Pain sensitivity and healing of hot-iron cattle brands. *Journal of Animal Science,* 92:5674–5682.

Vickers, K. J., Niel, L., Kiehlbauch, L. M. & Weary, D. M. (2005). Calf Response to Caustic Paste and Hot-Iron Dehorning Using Sedation With and Without Local Anesthetic. *Journal of Dairy Science*, *88*(4), 1454–1459.

Ward J. L., Rebhun W.C. (2012). Chronic frontal sinusitis in dairy cattle: 12 cases. *Veterinary Medical Association,* 201:326-328.

Weary, D.M., (2000). Dehorning dairy calves. *Animal Welfare Programm*, University of British Colombia, Vancouver, Canada. 245-256.

Winder, C. B., LeBlanc, S. J., Haley, D. B., Lissemore, K. D., Godkin, M. A. & Duffield, T. F. (2017). Clinical trial of local anesthetic protocols for acute pain associated with caustic paste disbudding in dairy calves. *Journal of Dairy Science*, *100*(8), 6429–6441.